

Economic evaluation of the trilateral FTA among China, Japan, and South Korea with big data analytics

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ABSTRACT

This study quantitatively analyzes the impact of a free trade agreement (FTA) among China, Japan, and South Korea using big data analytics. Using game theory and the computable general equilibrium approach, it proposes a compromise between the two countries for agricultural protection, to reduce possible divergences and confrontations. The findings show that game results differ among the three countries as per interest indexes. Compared to full tariff exemption, an FTA with agricultural protection not only stimulates economic growth in the three countries but also reduces Japan and South Korea's agricultural concerns and impact on employment. We also evaluate the impacts of the trilateral FTA on manufacturing and services industries. The results show that China will increase imports of energy-intensive products from Japan and South Korea, which may reduce domestic output and generate environmental benefits. Implementing the trilateral FTA with agricultural protection may reduce carbon emission in Northeast Asia by 6.53 million tons. This study can promote economic integration in Northeast Asia and coping with climate change. The analysis also highlights the importance of lifecycle management of energy-intensive industries in China, Japan, and South Korea.

1. Introduction

In past decades, the size of Northeast Asia's economy, especially those of China, Japan, and South Korea, have expanded significantly, making it the world's third largest economic force, following the European Free Trade Association (EFTA) and North American Free Trade Agreement (NAFTA). However, Northeast Asia significantly lags behind the other two regions in development due to the lack of institutional economic integration between China, Japan, and Korea (Li & Whalley, 2017). This situation is inconsistent with both the surging trends in global free trade agreements (FTA) and the trading ties among them. Although political relations among the three countries have been at low ebb in recent years, their economies largely depend on each other. In fact, they have formed a community with a solid foundation to negotiate a trilateral FTA (Nagayasu, 2010). The economies of these three countries are export-oriented, outward looking, and are liable to be affected by external affairs. An FTA among these three countries can optimize resource allocation, enhance competitiveness in advantaged industries, and enhance resistance to economic crises emerging outside the region (Kawai, 2015).

Although the progress of the FTA among China, Japan, and South

Korea is slow, they continue to strive for economic integration in Northeast Asia, leading to multiple rounds of negotiations and discussions. The China–Japan–South Korea trilateral summit in 2002 was where China first suggested an FTA among the three nations (Ye, 2017). In May 2012, the fifth China–Japan–South Korea trilateral summit concluded with the official signing of the China–Japan–South Korea investment agreement. The first round of the trilateral FTA was held in March 2013 in South Korea, where topics such as institutional arrangement, negotiation fields, and potential steps were emphasized. In November 2015, the three countries published a joint statement, reiterating that they would further accelerate relevant negotiations to sign a comprehensive, high-level, and mutually beneficial trade agreement. The ninth round of the China–Japan–South Korea FTA was held in January 2016 in Tokyo, where the three parties exchanged ideas on various subjects, including cargo and service trades and investments. All three nations are important economic global entities, and thus, an FTA among them can further integrate a value chain in Northeast Asia and significantly affect global political and economic patterns (Lee & Park, 2005).

Since its proposal, the trilateral FTA has attracted much attention. The literature comprises research mainly on the following aspects. First,

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some scholars discuss potential opportunities, implementation, and main challenges of the China–Japan–South Korea FTA and generally consider significant economic benefits from trilateral FTA. There are concerns about complex political relationships, disturbance from countries outside the region, tension in the Korean Peninsula, and sensitive industries in Japan and South Korea. These factors have significantly hindered cooperation between the three countries (Dreyer, 2014; Hamanaka, 2012; Madhur, 2013; Takahashi, 2010; Yoshimatsu, 2015; Zhang, 2016, 2018). Takahashi (2010) highlighted the importance of agriculture-related problems in discussions on economic integration in East Asia and each country's concerns about agricultural damages as the primary obstacles in the FTA. Hamanaka (2012) noted that the China–Japan FTA is a difficult feat for two reasons: political conflicts between the two countries and both countries wanting to be political and economic leaders in the region. Yoshimatsu (2015) researched interest bias during FTA negotiations among China, Japan, and South Korea and highlighted that the strategies of the three countries mainly served the political and economic evolution in the Asia-Pacific region. Clearly, the abovementioned studies are mainly qualitative analyses with a rare quantitative study.

Second, the computable general equilibrium (CGE) is a powerful tool for evaluating the economic influence of FTAs (Li & Whalley, 2017; Xiang, Kuang, & Li, 2017). Many scholars used the CGE model to evaluate the economic effects of the China–Japan–South Korea FTA and found significant improvements in the level of trade in Northeast Asia, stimulated economic growth, and improved welfare in each country. However, the effects of the FTA on industries differ in each country. Chirathivat (2004) adopted the CGE model to simulate the economic influence of the East Asian FTA and revealed that in the long run, the resultant benefits would be higher than the production cost, although the economic benefits would vary by country. Eor, Kim, and Heo (2005) examined the influence of the trilateral FTA on South Korea's agricultural sector using the KREI-ASMO model and showed that total agricultural revenue significantly decreased from 14% to 22%. Peng and Zhang (2012) performed a numerical simulation of the economic benefits from the trilateral FTA and found significant negative impacts of the FTA on comparatively inferior industries in Japan and South Korea and similar influences on China's chemical, rubber and plastic products, and steel metal industries. Zhao, Chen, and Gao (2013) analyzed the economic effects of the trilateral FTA in different periods using a dynamic recurrent CGE model and found that the most sensitive industries in Japan were textile and agriculture, which were also highly sensitive in South Korea. These studies showed that Japan and South Korea's concerns about agricultural issues served as key obstacles in signing the China–Japan–South Korea FTA, despite its economic effects.

Finally, signing the trilateral FTA would certainly accompany complex game playing in terms of political and economic interests. Some scholars analyzed the three-party game problem during the FTA signing process using game theory models, focusing on the feasibility of the transition from a bilateral to trilateral FTA. Mukunoki and Tachi (2006), using a dynamic game theory model, revealed that bilateral FTA in axle-spoke form could stimulate multilateral free trade more easily. Ma, Zhang, and Zhang (2008) simulated and analyzed all possible forms of the FTA among China, Japan, and South Korea and revealed that a trilateral FTA among the nations was a Nash equilibrium solution to the three-party game. In addition, their results indicated that all bilateral FTAs among the three countries could stimulate the trilateral FTA. Nomura, Ohkawa, Okamura, and Tawada (2013) explored the function of a bilateral FTA on multilateral free trade in countries with different economic sizes and demonstrated that in the axle-spoke form, while bilateral FTAs between larger countries would stimulate multilateral free trade those between smaller ones might have opposite effects.

In sum, the FTA among China, Japan, and South Korea is yet to progress sufficiently, owing to the lack of trust in politics and the unwillingness to make economic compromises (Zhang, 2016). At present,

China holds a positive attitude toward the trilateral FTA, while Japan and South Korea remain passive (Yoshimatsu, 2015). Some studies indicate that this possibly due to Japan's and South Korea's concerns about the impact of the FTA on their agricultural industries once they fully open their markets (Chirathivat, 2004; Eor et al., 2005; Madhur, 2013; Mulgan, 2008; Takahashi, 2010), as agriculture plays a crucial role in both countries. The negotiations for the trilateral FTA are essentially a process of game playing among the three parties in which they hope for minimal impact on their inferior industries and further development of advantaged ones. During game playing, all three countries change their strategies as per domestic conditions, choosing whether to sign the FTA and its form, such that it maximizes their interests.

However, the extant literature has the following deficiencies. First, many scholars use the GTAP model to evaluate the economic effect of the trilateral FTA; however, they mostly reference the database published prior to the eighth version, and thus, do not reflect recent conditions. Second, existing research rarely focuses on the influences of the FTA on the employment market. The possible unemployment issues from the impact on sensitive industries could affect the strategic choices of the three countries. Finally, there is limited research on the environmental effects of economic integration in Northeast Asia. Further, the effects of the trilateral FTA on global carbon emission are also worth studying given the high carbon emissions in all three countries (Belkhir, Bernard, & Abdelgadir, 2017; Raheem & Ogebe, 2017; Urata, Yamada, Itsubo, & Inoue, 2017).

Using big data analytics, this study combines game theory and a CGE model and establishes decision-making indexes from an economic and employment viewpoint to analyze the game playing process of the trilateral FTA. Considering the concerns of Japan and South Korea about their agricultural markets, and to increase the two countries' enthusiasm for participation, this study proposes a compromised scheme for the China–Japan–South Korea FTA with agricultural protection. Further, using the GTAP model, it conducts a quantitative analysis of this scheme considering the economy and carbon emission. This study also analyzes the impacts of the trilateral FTA on manufacturing and services industries, and explores how to achieve green development of these industries in terms of lifecycle management.

2. General trade situation between China, Japan, and South Korea

To explore the economic effects of the China–Japan–South Korea FTA from the trade liberalization perspective, it is important to first analyze the general situation of economic development and differences in the industrial structures to understand economic complementarity and competitiveness among different countries and the potential opportunities for cooperation among them. This section compares the differences between China, Japan, and South Korea and analyzes the general conditions from an industrial structure and bilateral trade perspective to understand the historical foundation and development potential for regional economic and trade cooperation.

Table 1 shows certain important economic indexes for the three countries. It appears that Japan and South Korea surpass China in economic development. In 2016, Japan's GDP per capita was 38900.60 USD, whereas that of China was 8123.20 USD. However, China outperformed both Japan and South Korea in the economic aggregate. In 2016, China's GDP was 11.20 trillion USD, the second highest in the world, and far surpassed Japan's 4.94 trillion USD and South Korea's 1.41 trillion USD. As for import and export trades, the rate of foreign trade among each country was similar and became an important driving force of economic growth. For example, in 2016, China's import and export trades were 1950.37 billion USD and 2199.97 billion USD, which accounted for 19.64% and 17.42% of its GDP, respectively. The industrial structure suggests significant differences and strong complementarity among the three countries. In particular, China is a predominantly agrarian country whose agricultural value added is 8.60%

Table 1
The economic index of three countries in 2016.

	China	South Korea	Japan
Population (million)	1378.67	51.25	126.99
GDP (USD trillion)	11.20	1.41	4.94
GDP growth rate (%)	6.70	2.80	1.00
GDP per capita (USD)	8123.20	27538.80	38900.60
Exports (USD billion)	2199.97	596.08	797.49
Imports (USD billion)	1950.37	500.17	745.65
Agriculture, value added (% of GDP)	8.60	2.20	1.10
Industry, value added (% of GDP)	39.80	38.60	25.50
Service, value added (% of GDP)	51.60	59.20	73.40

Source: World Bank website.

of its GDP, which is considerably higher than Japan's 1.10% and South Korea's 2.20%. On the other hand, Japan has the most developed services sector and its value added is 73.40% of its GDP, which is considerably higher than China's 51.60%. However, South Korea's industry is more developed than that of Japan. In general, while the three countries are geographically adjacent and have close trade relationships, they have significant differences. Utilizing its own advantages, China can complement the advantages of other countries for development and resulting in a win-win situation.

Although there is much potential for economic cooperation between China, Japan, and South Korea, the FTA remains in the negotiation stage, as opposed to other key FTAs in the world. Table 2 presents the comparative results for three of the world's key trade zones. It shows that the population in the trade areas of China, Japan, and South Korea's was 1556.91 million, which is 20.92% of the world's total population and far exceeds the EFTA's 6.87% and the NAFTA's 4.83%. The total GDP of the three FTAs were generally equivalent. In Northeast Asia, the economic aggregate is 17.55 trillion USD, which is about 23.14% of the world's total level and higher than the EFTA's 21.74% but lower than the NAFTA's 26.58%. Table 2 also shows that the trade scale of China–Japan–South Korea was more limited than the EFTA. The accumulated trade volume for China, Japan, and South Korea was 3593.54 billion USD, which is lower than the EFTA's 7239.98 billion USD. This indicates the large consumption and economic growth potential of the Northeast Asia trade zone.

China, Japan, and South Korea are pillars of the Asian economy and important economic entities in the world. In recent years, the three countries have established increasingly close trade connections and become important trade partners and objective markets to each other. Fig. 1 lists the changes in trade between China, Japan, and South Korea from 2000 to 2016, indicating a trend of rapid growth in trade cooperation. Exports from China to South Korea increased from 11.29 billion USD in 2000 to 93.71 billion USD in 2016 and imports increased from 23.21 billion USD to 158.97 billion USD during the same period. South Korea consistently reported a trade surplus with China. From 2000 to 2016, exports from China to Japan increased from 41.65 billion USD to 129.27 billion USD and those from Japan to China increased

Table 2
Comparison between China–Japan–South Korea FTA, EFTA, and NAFTA in 2016.

	Population		GDP		Export trade	
	Million	Ratio(%)	USD trillion	Ratio(%)	USD billion	Ratio(%)
China–Japan–South Korea	1556.91	20.92	17.55	23.14	3593.54	17.26
EFTA	511.50	6.87	16.49	21.74	7239.98	34.78
NAFTA	359.48	4.83	20.16	26.58	2691.43	12.93

Source: World Bank website.

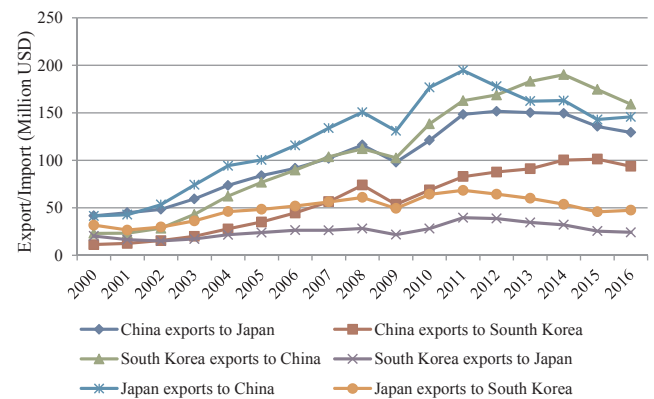


Fig. 1. Trilateral trade between China, Japan, and South Korea. Source: UN commodity trade statistics database: <https://comtrade.un.org/data/>

from 41.51 billion USD to 145.67 billion USD. China has maintained a trade deficit with Japan after 2002. Fig. 1 also shows that the level of trade between the three countries declined slightly in recent years, indicating that export-oriented economic development was liable to be affected by external factors.

The figure clearly shows a large economic aggregate for the three countries. Further, their industrial structures differ significantly and economic complementarity is strong. These are conditions necessary to realize economic integration between China, Japan, and South Korea. Compared with the NAFTA and EFTA, the degree of economic integration among China, Japan, and South Korea is somewhat insufficient and has much potential for development. In addition, while the three countries have weak export-oriented economic development, their regional economic integration is favorable for countering the impact of an economic crisis in the area. An FTA among China, Japan, and South Korea can help achieve economic integration in Northeast Asia. However, there is still no effective agreement among the three countries, and thus, it is necessary to analyze this phenomenon.

3. Model and method

The economic system, energy system, and environment system are very complex, and it is necessary to build large-scale models and advanced forecasting systems to capture the behavioral characteristics of all economic entities (Duan, Mo, Wang, & Fan, 2018; Song & Cui, 2016). The predicted plan is not prepared based only on, for example, forecasting techniques but big data. A huge volume of data was necessary for empirical analysis based on the large-scale models, generated from real-life environment or applications.

This study constructs a game framework for FTA negotiations between China, Japan, and South Korea using a non-cooperative static game with perfect information. The gains of each country are calculated on the basis of GTAP. The GTAP model is a global multi-region and multi-sector comparative CGE model. Under the GTAP model framework, economic policy changes in one country will not only generate domestic effects but also create ramifications in other countries through international trade and foreign investment. Fig. 2 illustrates the main structure of the GTAP model. It assumes a regional household account for each country to collect all income in the region. This amount of income is spent on private household consumption, government consumption, and savings, satisfying the Cobb–Douglas utility function; that is, the proportions of expenditure keep unchanged (Cui, Peng, & Zhu, 2015; Lee, Lam, & Lee, 2016). To calibrate the model with price elasticity, private household consumption is depicted by a non-homothetic constant difference of elasticity (CDE) and governmental consumption is presumed to be in the Cobb–Douglas function form. The GTAP model presumes a virtual global bank that collects savings from every country and redistributes investments globally as per the capital

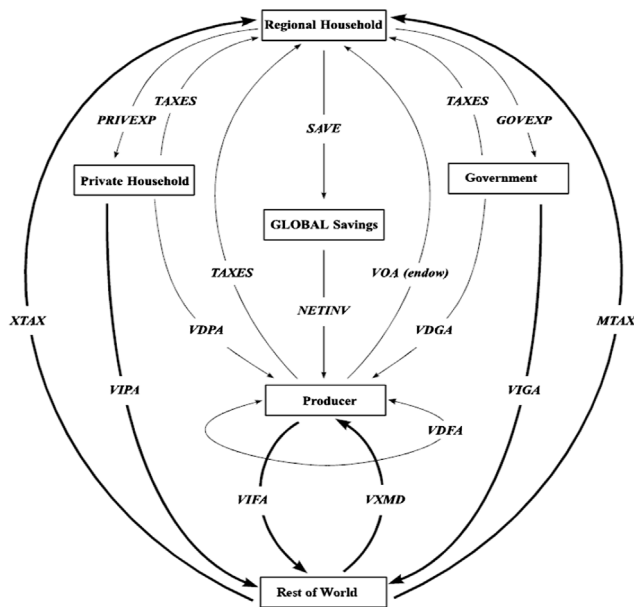


Fig. 2. GTAP model structure.
Source: Ha, Kompas, Nguyen, and Long (2017).

return rate and initial capital share of each country (Cui & Song, 2017; Cui et al., 2015; Siddig, Grethe, & Abdelwahab, 2016).

As for export trade, the GTAP model presumes that the products of one country are mainly used for domestic consumption. Further, export satisfies the constant elasticity of transformation (CET) and the distribution of sales volume satisfies the restriction of profit maximization. For import trade, the model assumes that imported and domestic products are heterogeneous and products from different countries can be imperfectly substituted but all products satisfy the Armington hypothesis (Avetisyan, Hertel, & Sampson, 2014). In terms of tariff barriers, it presumes that each country has two types of variables: import and export tariff, whose values are subdivided by specific industries to evaluate the effects of tariff concession. When using the GTAP model for simulation, the reduction in import tariff in one country reduces the domestic consumption price of imported products, increases demands for import, and decreases the competitive edge of similar domestic products. Under balanced supply and demand, relevant domestic industries may shrink and production factors may undergo a new round of dynamic regulation among industries, leading to change in industrial structure in that country. In sum, a slight change in the economic system can affect the whole situation. The elimination of tariff barriers has complex and profound effects on the economic system and the GTAP model can simulate such dynamic regulations efficiently. For more information on the GTAP model, see Carrico and Tsigas (2014) and Beckman, Hertel, and Tyner (2011).

The GTAP model has been widely used to quantitatively evaluate international economic and trade policies. In recent years, some scholars have also used such a model to evaluate the effects of free trade cooperation between China and other countries and acquired good policy effects. For example, Walmsley, Hertel, and Ianchovichina (2006) analyzed the influence of China's participation in the WTO on foreign direct investment. Ariyasajakorn, Gander, Ratanakomut, and Reynolds (2009) researched the income distribution effect of economic integration between China and the Association of Southeast Asian Nations (ASEAN). Cheong (2014) discussed the influence of a China–South Korea FTA on their economic growth, welfare improvement, and import and export trade. McDonald, Robinson, and Thierfelder (2014) adopted an economic integration perspective and quantitatively evaluated the effects of the FTAs by China and key Asian countries. Lee et al. (2016) analyzed the influences of economic integration in the Asia-Pacific

region on the carbon emission of seaborne trade. Thus, the GTAP model has become a powerful tool in evaluating the effects of regional economic integration and its results have been proven by relevant studies.

In this study, we discuss the negotiation problems of an FTA among China, Japan, and South Korea by simultaneously using game theory and a computable general equilibrium model. However, first, three elements require clarification when using game theory for empirical analysis: the player, policy space, and payoff function. This study treats China, Japan, and South Korea as players. The construction of the policy space set should consider both operability and completeness. The payoff function set is the most difficult to define, as there is no index to strictly evaluate whether a policy is good because it could improve certain economic indexes but hinder other indexes. Further, we construct a payoff function on the basis of real GDP and employment to discuss strategy selections by China, Japan, and South Korea.

3.1. Grouping of region, industry, and elements in GTAP model

The quantitative evaluation is conducted using the GTAP 9.0 database, which is a comparatively comprehensive global economic and trade database. The base period for simulation is 2011. The database not only depicts the complex independent relationship among industries within a country but also details bilateral global trades. The GTAP 9.0 database is a global economic database of regional input-output data, macroeconomic data, bilateral trade flows, energy data, and CO₂ emissions from fossil fuels. It contains the input-output tables and bilateral trade statistics for 57 sectors and 140 regions. The GTAP database embodies the features of big data, as it describes the operating rules of energy, environment, and economy on a global scale.

Given the need for problem analysis and availability of sector-level employment data for China, Japan, and South Korea, this study classifies the 140 countries or areas in the GTAP model into 4 groups: China, Japan, South Korea, and other areas in the world. The original 57 sectors are aggregated into three types: agriculture, industry, and service. The production structure comprises the input factors required for production activities and includes the five primary inputs of land, capital, skilled labor, unskilled labor, and natural resources, as well as intermediate inputs produced domestically and imported into the economy. Owing to data availability, skilled labor and non-skilled labor are combined into one group. To simulate the effects of the trilateral FTA on the employment market, we presume that the real wage rate is an exogenous variable that remains unchanged in the short term and the labor force supply is an endogenous variable determined by labor force demand (Bhaduri & Marglin, 1990; Kurzweil, 2002; Lima, de Miguel, Pereira, & Véliz, 2010; Vanzetti & Huong, 2006; Walmsley & Minor, 2013). To capture the unemployment situation in the GTAP model, the two variables “real wage (pfactreal)” and “labor employment (qo)” are swapped (Lee, Lo, & Lin, 2017).

Table 3 presents employment in different industries in China, Japan, and South Korea. It shows that China's agricultural sector far exceeds that of Japan and South Korea, irrespective of the number of employed or employment proportion. In 2016, China's total employment was 750.88 million, of which 208.74 million were engaged in agriculture (27.80%). On the other hand, the service industry in Japan and South Korea attracted more labor force. In 2016, 45.08 and 18.69 million persons were employed in Japan and South Korea's service industry, accounting for 69.60% and 70.00% of total employment. Thus, the employment structures vary significantly among the three countries: while agriculture in China is more developed, the service industry in Japan and South Korea has comparative advantages.

3.2. Construction of the game's three elements

As mentioned, China, Japan, and South Korea are players in the game. Table 4 shows a condition for policy space in the game. Table 4 includes not only a bilateral FTA among any two countries (e.g., C2, K2,

Table 3
Employment of three industries in China, Japan, and South Korea in 2016.

	Total employment (million)	Agriculture		Industry		Service	
		Employment (million)	Proportion (%)	Employment (million)	Proportion (%)	Employment (million)	Proportion (%)
China	750.88	208.74	27.80	179.46	23.90	362.68	48.30
South Korea	26.69	1.36	5.10	6.65	24.90	18.69	70.00
Japan	64.77	2.40	3.70	17.29	26.70	45.08	69.60

Source: World Bank website.

Table 4
Settings of policy space in China, Japan, and South Korea.

Denotes	Strategies	Specific description
C1	China's strategy 1	China maintains the status
C2	China's strategy 2	China reduces tariffs on imports from South Korea
C3	China's strategy 3	China reduces tariffs on imports from Japan
C4	China's strategy 4	China reduces tariffs on imports from South Korea and Japan
K1	South Korea's strategy 1	South Korea maintains the status
K2	South Korea's strategy 2	South Korea reduces tariffs on imports from China
K3	South Korea's strategy 3	South Korea reduces tariffs on imports from Japan
K4	South Korea's strategy 4	South Korea reduces tariffs on imports from China and Japan
J1	Japan's strategy 1	Japan maintains the status
J2	Japan's strategy 2	Japan reduces tariffs on imports from China
J3	Japan's strategy 3	Japan reduces tariffs on imports from South Korea
J4	Japan's strategy 4	Japan reduces tariffs on imports from China and South Korea

and J1) but also a trilateral FTA among three countries (i.e., C4, K4, and J4). According to permutation and combination theory, the policy space for each of the three countries contains four strategies. Thus, there are 64 strategy profiles in total.

The payoff function is the third element of the game. It mainly reflects the gains of players in different strategy profiles. An FTA is favorable for economic growth but impacts inferior industries in each country. Hence, this study selects economic growth and employment change as indexes to construct different payoff functions and analyze the game results of the trilateral FTA from different viewpoints.

4. Game analysis of China–Japan–South Korea FTA

This section explores the China–Japan–South Korea FTA game from an economic and employment perspective. A non-cooperative static game with perfect information is used and all three countries are assumed to be economically rational players.

4.1. Economic growth perspective

Table 5 presents the variation in China, Japan, and South Korea's GDP under 64 strategy profiles. An evaluation based on the GTAP model offers relevant results. The numbers in parentheses correspond to China, South Korea, and Japan. The scoring method reveals that the trilateral FTA among China, Japan, and South Korea is the Nash equilibrium for the final game and none of other trade agreement forms (e.g., bilateral FTA) among the three countries is stable. The dominant strategies for all three countries are to cooperate with each other and open up their markets, indicating that they would adopt a cooperative attitude toward breaking the status quo when only considering economic growth. Table 5 shows that if the FTA among China, Japan, and South Korea can be smoothly set up, China will report the highest

increment in GDP at 7 289.50 million USD, followed by Japan and South Korea with 3 239.75 USD million and 2 125.00 million USD, respectively.

The implementation of an FTA among China, Japan, and South Korea will have different effects on the economic growth of the three countries. As the industrial structures of the three countries differ significantly, the elimination of import tariffs will generate varying impacts on the industries in the three countries. In general, the trilateral FTA will positively push the output of industry and service in all three countries, although these influences may differ for agriculture. China has stronger comparative advantages in agriculture than Japan and South Korea. With Japan and South Korea eliminating tariffs on imports from China, agriculture exports will increase significantly, resulting in the expansion of domestic agricultural output in China. Fig. 3 shows that if the trilateral FTA can be established, China's agricultural output will increase by 0.79%, while those of Japan and South Korea will decrease by 0.12% and 0.35%, respectively.

4.2. Employment perspective

The elimination of tariff barriers will have a complex impact on sectors. A change in import and export demand will expand the output of certain sectors in one country, but will shrink that of some other sectors. This will break the original supply–demand balance. Although there is elasticity of substitution between labor and capital, given enterprises' dependence on original production technology and modes, the substitution may not be obvious in the short term. To observe the short-term impact of an FTA on China, Japan, and South Korea's employment markets, we assume that real wages are constant, labor force supply is determined by labor force demand, and unemployment exists when labor force demand is lower than the potential employment quantity. Given the current division of industries, changes in employment opportunities following the implementation of a policy can be expressed as follows:

$$\Delta QFE = \sum_{n=1}^3 QFE_n * qfe_n, \quad (1)$$

where ΔQFE is the variation in labor demand, QFE_n is the labor demand of sector n before policy simulation, and qfe_n is the percentage of variation in labor demand of sector n under the impact of the policy.

Table 6 presents the variations in China, Japan, and South Korea's employment under different strategy profiles; the numbers in parentheses correspond to China, Japan, and South Korea, respectively. The table shows that if a country opens its market, it will result in the decline of employment opportunities in that country, and all three countries have their own dominant strategy, that is, maintaining the status quo. Hence, when only considering employment, the Nash equilibrium of the game between China, Japan, and South Korea is that all three countries maintain the status quo. Table 6 also shows that the trilateral FTA can increase employment in China by 156 million persons but decrease that in South Korea and Japan by 3.52 million and 0.60 million, respectively. Thus, in addition to political factors, employment pressure can render Japan and South Korea unwilling to sign the trilateral FTA.

Table 5
Variation in the real GDP of China, Japan, and South Korea (million USD).

C1	J1	J2	J3	J4
K1	(0.00, 0.00, 0.00)	(522.50, -44.13, 658.00)	(-40.00, 297.38, 71.00)	(482.50, 253.25, 729.00)
K2	(427.50, 957.38, -54.50)	(949.50, 913.25, 604.00)	(387.50, 1254.75, 16.15)	(910.00, 1211.63, 674.50)
K3	(-351.00, 628.13, 306.00)	(171.50, 584.00, 964.50)	(-391.00, 925.50, 377.00)	(131.50, 881.38, 1035.00)
K4	(76.00, 1585.50, 252.00)	(598.50, 1541.38, 910.00)	(36.50, 1883.00, 322.50)	(559.00, 1838.75, 981.00)
C2	J1	J2	J3	J4
K1	(222.50, 1800.00, -65.00)	(2745.00, 1755.88, 593.50)	(2182.50, 2097.50, 6.00)	(2705.00, 2053.38, 664.00)
K2	(2649.50, 2757.50, -119.00)	(3172.00, 2713.38, 539.00)	(2610.00, 3054.88, -48.50)	(3132.50, 3010.75, 610.00)
K3	(1871.50, 2428.13, 241.50)	(2394.00, 2384.00, 899.50)	(1831.50, 2725.63, 312.00)	(2354.00, 2681.38, 970.00)
K4	(2298.50, 3385.63, 187.00)	(2821.00, 3341.38, 845.00)	(2259.00, 3683.00, 257.50)	(2781.50, 3638.88, 916.00)
C3	J1	J2	J3	J4
K1	(4517.50, -399.13, 1209.00)	(5039.50, -443.25, 1867.00)	(4477.50, -101.75, 1279.50)	(5000.00, -45.88, 1938.00)
K2	(4944.50, 558.25, 1154.50)	(5467.00, 514.13, 1813.00)	(4905.00, 855.63, 1225.50)	(5247.50, 811.50, 1883.50)
K3	(4166.50, 229.00, 1515.00)	(4688.50, 184.88, 2173.00)	(5076.00, 1439.63, 2189.50)	(4649.00, 482.25, 2244.00)
K4	(4593.50, 1186.38, 1460.50)	(5116.00, 1142.25, 2119.00)	(4554.00, 1483.75, 1531.50)	(5076.00, 1439.63, 2189.50)
C4	J1	J2	J3	J4
K1	(6740.00, 1400.88, 1144.00)	(7262.00, 1356.00, 1802.50)	(6700.00, 1698.38, 1215.00)	(7222.50, 1654.13, 1873.00)
K2	(7167.00, 2358.25, 1090.00)	(7689.50, 2314.13, 1748.00)	(7127.50, 2655.75, 1160.50)	(7649.50, 2611.63, 1818.50)
K3	(6388.50, 2029.00, 1450.00)	(6911.00, 1984.88, 2108.50)	(6349.00, 2326.38, 1521.00)	(6871.50, 2282.25, 2179.00)
K4	(6816.00, 2986.38, 1396.00)	(7338.50, 2942.25, 2054.00)	(6776.00, 3283.88, 1466.50)	(7289.50, 3239.75, 2125.00)

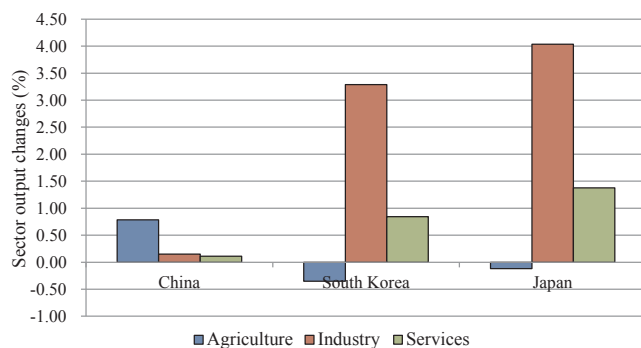


Fig. 3. Sectoral output changes of China–Japan–South Korea FTA.

The above analysis suggests varying game results for the China–Japan–South Korea FTA under different interest perspectives. From the economic growth perspective, the three countries will choose to cooperate but an increase in Japan and South Korea's economic aggregate will take place at the cost of agriculture. From the employment perspective, the three countries will choose to maintain the status quo. Given its comparative advantages in agriculture, China's agricultural output after a tariff concession will increase considerably, while that of Japan and South Korea will face major negative impacts. This will result in reduced employment opportunities in Japan and South Korea and they will adopt a wait-and-see attitude toward the trilateral FTA. For China, signing the trilateral FTA is superior to maintaining the status quo, as it increases not only actual GDP by 7289.50 million USD but also employment opportunities by 1.56 million. This explains China's eagerness to establish the trilateral FTA.

Table 6
Variation of employment opportunities in China, Japan, and South Korea (Million).

C1	J1	J2	J3	J4
K1	(0.00, 0.00, 0.00)	(67.99, -0.09, -0.25)	(-0.27, 1.67, -0.06)	(66.72, 1.57, -0.30)
K2	(92.46, -3.53, -0.01)	(160.42, -3.62, -0.26)	(91.20, -1.86, -0.06)	(159.15, -1.96, -0.31)
K3	(0.23, -0.76, -0.01)	(68.22, -0.86, -0.25)	(-1.03, 0.90, -0.06)	(66.95, 0.81, -0.31)
K4	(92.67, -4.29, -0.02)	(160.00, -4.39, -0.27)	(91.40, -2.63, -0.07)	(159.42, -2.72, -0.32)
C2	J1	J2	J3	J4
K1	(-5.06, -0.93, 0.01)	(62.95, -1.02, -0.23)	(-6.30, 0.74, -0.04)	(61.68, 0.64, -0.29)
K2	(87.40, -4.46, 0.00)	(155.39, -4.55, -0.24)	(86.13, -2.79, -0.05)	(154.14, -2.89, -0.30)
K3	(-4.80, -1.69, 0.01)	(63.16, -1.79, -0.24)	(-6.05, -0.03, -0.05)	(61.94, -0.12, -0.29)
K4	(87.63, -5.22, -0.01)	(155.62, -5.32, -0.25)	(86.42, -3.56, -0.06)	(154.38, -3.65, -0.31)
C3	J1	J2	J3	J4
K1	(-1.63, 0.13, -0.29)	(66.61, 0.04, -0.54)	(-0.38, 1.80, -0.35)	(65.39, 1.71, -0.59)
K2	(91.09, -3.40, -0.30)	(158.10, -3.49, -0.55)	(90.84, -1.73, -0.36)	(150.83, -1.83, -0.60)
K3	(-1.88, -0.63, -0.30)	(65.87, -0.73, -0.55)	(-1.07, -2.59, -0.61)	(64.60, 0.94, -0.60)
K4	(91.35, -4.16, -0.31)	(152.31, -4.26, -0.56)	(90.08, -2.50, -0.36)	(141.07, -2.59, -0.61)
C4	J1	J2	J3	J4
K1	(-4.85, -0.74, -0.38)	(63.08, -0.83, -0.36)	(-4.66, 0.87, -0.33)	(63.33, 0.77, -0.58)
K2	(89.05, -4.33, -0.29)	(157.03, -4.42, -0.53)	(87.78, -2.66, -0.34)	(155.79, -2.76, -0.59)
K3	(-3.15, -1.56, -0.28)	(64.83, -1.66, -0.53)	(-4.42, 0.11, -0.34)	(63.57, 0.01, -0.59)
K4	(89.28, -5.09, -0.30)	(157.27, -5.19, -0.54)	(88.04, -3.43, -0.35)	(156.00, -3.52, -0.60)

Table 7
The trilateral FTA with agricultural protection and agricultural liberalization.

	Changes in the real GDP (unit: %)		Increment of employment opportunities (unit: million persons)	
	Agricultural liberalization	Protection of agriculture	Agricultural liberalization	Protection of agriculture
China	0.10	0.09	156.00	70.15
South Korea	0.27	0.24	−3.52	−2.24
Japan	0.04	0.03	−0.60	−0.49

4.3. China–Japan–South Korea FTA with agricultural protection

The preceding analysis indicates that employment is a key factor hindering FTA negotiations among China, Japan, and South Korea. Therefore, relieving the employment burden will depend on the direction of each country's endeavor toward future negotiations. Given China's agricultural superiority, Japan and South Korea are opposed to agricultural liberalization (Chirathivat, 2004; Choi & Oh, 2011; Desker, 2004; Eor et al., 2005; Madhur, 2013; Mulgan, 2008; Takahashi, 2010; Ye, 2017). This study proposes a compromised strategy that reduces agricultural tariff by half and eliminates the tariffs of other sectors—in sum, this is an FTA with agricultural protection.

Table 7 compares and analyzes the effects of the two policies: agricultural protection, and agricultural liberalization, from two perspectives: the real GDP and employment. Compared with agricultural liberalization, the trilateral FTA with agricultural protection will improve unemployment in Japan and South Korea to different degrees. Further, the number of persons employed in South Korea and Japan will reduce by 2.24 and 0.49 million persons, respectively, which are 1.28 and 0.11 million persons less than that under the case of agricultural liberalization. Table 7 also shows that the varying increases in the real GDP of all three countries under agricultural protection and the amplification will be lower than under agricultural liberalization; the GDPs of China, South Korea, and Japan will increase by 0.09%, 0.24%, and 0.03%, respectively. Thus, the trilateral FTA with agricultural protection will be more helpful in reducing the unemployment concerns in Japan and South Korea.

5. Economic and environmental influences of China–Japan–South Korea FTA with agricultural protection

This section evaluates the environmental and economic effects of the trilateral FTA with agricultural protection using the GTAP model. The economic effects can be mainly observed on sectoral output and sectoral import and export trades, whereas the environmental effects can be seen in the variations in CO₂ resulting from output in each sector. To evaluate the specific effects of the trilateral FTA on different sectors in the three countries, the original 57 industries of GTAP are aggregated into 13 sectors by referencing Yoon, Gong, and Yeo (2009) and Cui, Sun, and Song's (2016) classification of industries. See Table 8 for details.

5.1. Economic effect

5.1.1. Sectoral output changes

Tariff elimination will lead to changes in the prices and quantity of import and export trades among China, Japan, and South Korea. Such changes will eventually be reflected in import demand for bilateral consumers. A variation in demand will lead to change in production of enterprises. Following a comparison of competitive advantages of commodities, enterprises will aim to increase the comparative advantages of their products or scale this effect in their home countries, resulting in the clustering of capital and labor force in these industries.

Table 9 lists the effects of the trilateral FTA on the outputs of different sectors in the three countries. We see that the textile industry reports the most significant expansion owing to a tariff concession: an increase of 12136.82 million USD with an amplification of 1.21%. Industries in South Korea that benefited the most from the tariff concession were the chemical and machinery and equipment, with an increase of 8110.87 million USD and 5981.47 million USD, with amplifications of 2.17% and 3.12%, respectively. Japan's construction services showed the most significant output expansion, with an increase of 7784.63 USD and an amplification of 1.17%. However, the trilateral FTA will negatively affect sensitive industries in all three countries, as the elimination of tariff barriers will enhance the competitiveness of advantageous industries and most resources (including labor force and capital) will be released from other industries to advantaged ones. However, this situation is unfavorable for industries with weak competitive force and their output level will decline. Table 9 shows that the motor vehicle and transport equipment industry suffered the most in China, with a decrease of 1.7%, and in South Korea and Japan, it was the electronic equipment industry and the textile industry, with a decrease of 1.86% and 3.65%, respectively.

5.1.2. Variation in import and export trades

Table 10 presents the impacts of the trilateral FTA with agricultural protection on the import and export trades of all sectors in each country. In general, with concession in import tariff, imported products have comparative advantages against domestic products and import demands in most sectors will increase. In China and South Korea, the highest increase in imports was reported in machinery and equipment, with a growth of 15524.37 million USD and 5866.81 million USD and amplifications of 5.41% and 8.37%, respectively. In Japan, it was the textile industry with an increase of 5871.02 million USD and amplification of 12.65%. The effects of a FTA on sectors' export also differed in the three countries. In China, the sector with the highest output increase was the textile sector, with an increase of 10179.49 million USD and amplification of 3.00%. In South Korea, it was the machinery and equipment sector with an increase of 9602.30 billion USD and amplification of almost 9.05%. Finally, in Japan, the chemical industry experienced the highest increase in output with an increase of 5886.08 billion USD and amplification of 4.53%.

Table 10 also indicates that the increase in imports of some energy intensive products and heavy industries in China, such as pulp, paper and wooden products, chemical, iron and metal, motor vehicles and transport equipment, and machinery and equipment, were higher than increase in exports. The negative output variations for these sectors (Table 9) suggest that the substitution of domestic products with imported ones by domestic consumers was the key reason underpinning the output decline in these sectors. Such a finding is notable, as China currently faces overcapacity in energy intensive industries.

Table 11 presents the influences of the trilateral FTA with agricultural protection on economic and trade contacts among the three countries. The trade creation effect can significantly enhance trade contacts among the three countries along with the exemption of import and export tariffs. In particular, the Chinese agricultural and textile industries are competitive industries whose exports to South Korea increased by 3352.99 and 3081.69 million USD and to Japan by 2677.07 and 10378.73 million USD, respectively. South Korea's machinery and equipment industries experienced the highest expansion in exports to China of about 13889.89 million USD and amplification of almost 31.28%. The increase in the chemical industry's exports from South Korea to Japan was the highest (about 1142.13 million USD) with the establishment of the FTA. The increase in exports from Japan to China is mainly in motor vehicles and transport equipment, with an increase of 12286.12 million USD and 15533.96 million USD and amplifications of 57.27% and 21.67%, respectively. The sectors with the most significant expansion in exports from Japan to South Korea were machinery and equipment, and chemical industries, with increases of

Table 8
Sectoral aggregation with GTAP model.

Description	Sectors included in GTAP
Agriculture	Rice, wheat, other grains, vegetables, fruits, nuts, oilseeds plants, cane, beetroot, plant fiber, other crops, cattle, sheep, horse, other animal products, raw milk, wool, silkworm cocoon, forestry, fishery, beef, mutton, horsemeat and other meat products, plant oil, articles of everyday use, rice, sugar making industry, other food processing industries, tobacco and relevant products
Mining	Coal, petroleum, natural gas and relevant products, other minerals
Textile products	Textile, clothing, leather products
Pulp, paper and wooden	Woodware, printing and publishing industry
Chemical	Chemical industry, plastics and rubber
Iron and metal	Iron, other metals and metal products
Motor vehicles and transport equipment	Motor vehicles and parts, other transportation facilities
Electronic equipment	Electronic equipment
Machinery and equipment	Machinery
Other manufactures	Other manufacturing industry
Electricity, gas manufacture and water industry	Electricity, gas and water production and supply industry
Construction service	Construction service industry
Other services	Construction, transportation, financial service and entertainment and other serve industries

4667.51 million USD and 3551.52 million USD and amplifications of 23.07% and 18.85%, respectively. Thus, the trilateral FTA can significantly stimulate trade levels; however, given the differing competitive edges of various products and coverage and tariff barrier levels, trade expansion among the three countries demonstrates strong industrial heterogeneity.

5.2. Carbon emission changes

5.2.1. Influences of the trilateral FTA with agricultural protection on regional carbon emission

Currently, global warming is a highly debated topic across the world and effective control of greenhouse gas emissions is an inevitable measure to counter climate change. Thus, this study treats CO₂ as a research objective to quantitatively measure the influence of the trilateral FTA with agricultural protection on the regional environment. Assuming that technical progress remains constant in the short run, industrial CO₂ emission will be mainly determined by industrial output:

$$REco2 = \sum_{k=1}^n c_k QO_k, \quad (2)$$

where $REco2$ is CO₂ emission variation under the impact of a certain trade policy; QO_k is the output variation of sector k ; c_k is the CO₂ emission intensity for sector k , specifically, the ratio of CO₂ emission to the corresponding output; and n is the number of sectors. Data on the CO₂ emission of all sectors for each country in the base period are from the GTAP 9.0 database. Using Eq. (2), we can compute the CO₂ emission variation for each sector in China, Japan, and South Korea. Table 12

shows the specific results.

Table 12 shows us that China's sectoral CO₂ emission intensity was higher than that of both Japan and South Korea and this difference is greater among various industries, indicating China's potential for emission reduction. At the national level, the implementation of the trilateral FTA with agricultural protection would reduce China's CO₂ emission by 7802.12 thousand tons, while those in Japan and South Korea would slightly increase by 736.39 and 538.56 thousand tons. Nevertheless, the CO₂ emission level for Northeast Asia would reduce by 6527.17 thousand tons, which is 0.08% of its total carbon emission in 2011. Therefore, the implementation of the China–Japan–South Korea FTA with agricultural protection is will propel emission reduction in the three regions. From the perspective of sectoral emissions, because of output expansion, the trilateral FTA would increase CO₂ emissions from the agricultural, textile, and construction services, of which the increase for the textile industry would be up to 531.63 thousand tons. Undoubtedly, the trilateral FTA could also stimulate CO₂ emission reduction in certain industries, for example, 2904.61 thousand tons of emission could be reduced in the electricity, gas manufacture, and water industry.

In general, the trilateral FTA with agricultural protection would reduce total CO₂ emission in Northeast Asia by 6527.17 thousand tons, primarily attributable to China's abatement due to emission reduction in the electricity, gas manufacture, and water industry (50% of total CO₂ emission reduction). Therefore, it is necessary to explore the reasons for this drastic reduction.

Table 9
Sectoral output changes in the trilateral FTA with agricultural protection.

	China		South Korea		Japan	
	Output (\$ Mil)	Percentage (%)	Output (\$ Mil)	Percentage (%)	Output (\$ Mil)	Percentage (%)
Agriculture	7925.40	0.38	−1161.16	−0.88	−3606.24	−0.65
Mining	−858.90	−0.15	−72.91	−1.85	−211.85	−1.67
Textile products	12136.82	1.21	782.01	1.57	−2675.75	−3.65
Pulp, paper and wooden	−295.70	−0.05	−518.13	−1.21	−1350.63	−0.70
Chemical	−9877.38	−0.47	8110.87	2.17	3869.18	0.48
Iron and metal	−4912.12	−0.20	−3089.85	−0.97	−2387.45	−0.37
Motor vehicles and transport equipment	−9552.31	−1.07	−3365.37	−1.67	−815.44	−0.14
Electronic equipment	3664.29	0.38	−4039.92	−1.86	−1780.04	−0.47
Machinery and equipment	−11492.45	−0.61	5981.47	3.12	−2925.10	−0.55
Other manufactures	−827.86	−0.23	−592.96	−1.36	83.60	0.10
Electricity, gas manufacture and water industry	−334.54	−0.10	134.22	0.24	310.63	0.12
Construction service	6096.00	0.33	3598.60	2.01	7784.63	1.17
Other services	−871.52	−0.02	−1422.13	−0.12	852.35	0.01

Table 10

Sectoral import and export changes in the trilateral FTA with agricultural protection (USD million; %).

	China		South Korea		Japan	
	Export	Import	Export	Import	Export	Import
Agriculture	5308.93 (9.38)	1315.68 (1.16)	937.43 (15.77)	1624.33 (5.78)	− 18.12 (− 0.33)	3469.19 (4.45)
Mining	112.52 (1.57)	− 1530.96 (− 0.43)	20.30 (4.77)	2088.26 (1.40)	70.74 (9.35)	805.55 (0.35)
Textile products	10179.49 (3.00)	2446.09 (5.09)	2035.02 (12.00)	1684.55 (10.68)	2603.42 (25.11)	5871.02 (12.65)
Pulp, paper and wooden	265.79 (0.35)	311.26 (0.82)	− 101.64 (− 2.03)	248.84 (3.49)	− 79.62 (− 1.09)	1034.04 (4.65)
Chemical	2432.00 (1.15)	7283.33 (2.74)	8752.38 (7.53)	3833.20 (5.20)	5886.08 (4.53)	3618.21 (2.91)
Iron and metal	2524.23 (1.35)	3199.93 (2.46)	− 77.33 (− 0.15)	2624.07 (4.45)	− 83.40 (− 0.09)	2281.90 (4.31)
Motor vehicles and transport equipment	1941.37 (2.39)	7587.58 (7.67)	− 2225.89 (− 2.01)	1100.29 (5.40)	− 435.43 (− 0.25)	1446.92 (4.93)
Electronic equipment	7353.28 (1.74)	4396.60 (2.16)	− 2170.30 (− 2.30)	1480.41 (2.81)	1192.31 (1.36)	4123.55 (5.50)
Machinery and equipment	8564.21 (2.34)	15524.37 (5.41)	9602.30 (9.05)	5866.81 (8.37)	− 580.41 (− 0.22)	4843.88 (5.35)
Other manufactures	− 18.78 (− 0.02)	518.89 (3.59)	− 115.26 (− 4.68)	463.70 (12.59)	290.61 (3.08)	615.57 (5.64)
Electricity, gas manufacture and water industry	− 8.88 (− 0.39)	3.93 (0.19)	− 0.98 (− 3.63)	7.16 (3.31)	− 3.20 (− 7.71)	18.64 (4.38)
Construction service	20.13 (0.28)	− 27.32 (− 0.56)	− 448.67 (− 4.13)	47.33 (1.81)	− 725.38 (6.15)	454.16 (4.15)
Other services	26.61 (0.01)	202.29 (0.12)	− 1384.63 (− 3.44)	2702.13 (3.26)	− 3184.61 (− 4.11)	4608.28 (3.44)

5.2.2. Carbon emissions changes in China's electricity, gas manufacture, and water industry

First, as we use the comparatively static GTAP model, the reduction in carbon emission from the electricity, gas manufacture, and water industry will be mainly due to an output decline, if we assume that technical progress is constant in the short run. In addition, the demand for electricity, gas manufacture, and water industry will also decline due to balanced supply and demand. Second, because there is no tariff

barrier in this sector, trade liberalization will not significantly change related to import demand. This indicates that a decrease in domestic demand leads a decline in the industry's total demand. Among others, the chemical, and iron and metal industries have the highest demand for electricity, gas manufacture, and water industry. According to the GTAP 9.0 database, the intermediate demands of the two industries for electricity, gas manufacture, and water accounted for about 40% of the total output of the latter. Therefore, we chose the chemical and iron and

Table 11

The impacts of the trilateral FTA with agricultural protection on economic and trade contacts among the three countries (USD million;%).

	From China		From South Korea		From Japan	
	To South Korea	To Japan	To China	To Japan	To China	To South Korea
Agriculture	3352.99 (82.64)	2677.07 (24.38)	342.79 (34.14)	624.89 (31.10)	51.03 (5.25)	211.88 (40.58)
Mining	126.46 (11.83)	3.61 (0.31)	32.58 (11.63)	− 6.78 (− 8.00)	70.71 (21.04)	28.47 (20.09)
Textile products	3081.69 (37.64)	10378.73 (31.51)	1799.08 (45.19)	146.30 (16.90)	2369.01 (51.91)	186.84 (42.30)
Pulp, paper and wooden	294.57 (16.49)	534.60 (8.73)	159.24 (15.37)	− 10.15 (− 2.67)	305.42 (10.15)	− 29.57 (− 5.53)
Chemical	2468.58 (22.12)	507.38 (2.89)	8566.72 (19.01)	1142.13 (9.61)	6717.95 (20.59)	3551.52 (18.85)
Iron and metal	2275.80 (13.44)	677.33 (5.65)	1924.18 (20.00)	96.34 (1.28)	4468.27 (20.36)	1051.94 (7.61)
Motor vehicles and transport equipment	365.55 (9.80)	255.42 (5.94)	3486.76 (55.10)	− 13.89 (− 1.39)	12286.12 (57.27)	809.03 (28.83)
Electronic equipment	1542.96 (7.13)	2213.44 (6.41)	2485.81 (8.77)	− 134.91 (− 2.26)	7918.30 (24.04)	− 362.82 (− 6.94)
Machinery and equipment	4843.96 (31.14)	1903.65 (5.80)	13889.89 (31.28)	− 101.97 (− 1.89)	15533.96 (21.67)	4667.51 (23.07)
Other manufactures	421.51 (29.54)	387.86 (6.54)	58.60 (14.60)	21.10 (7.09)	908.32 (47.74)	161.73 (20.92)
Electricity, gas manufacture and water industry	0.78 (2.91)	1.39 (3.94)	− 0.21 (− 4.52)	− 0.02 (− 0.35)	− 0.63 (− 7.66)	− 0.11 (− 4.52)
Construction service	3.05 (2.34)	25.73 (4.95)	− 25.67 (− 4.07)	− 7.04 (− 0.28)	− 54.93 (− 5.05)	− 15.64 (− 3.87)
Other services	336.91 (2.87)	559.28 (2.94)	− 204.47 (− 6.47)	− 167.63 (− 3.40)	− 533.03 (− 6.50)	− 151.47 (− 3.50)

Table 12
CO₂ emissions changes in the trilateral FTA with agricultural protection.

	China		South Korea		Japan		Total
	Carbon intensity (1000tons CO ₂ /USD1million)	Carbon emission changes (1000tons CO ₂)	Carbon intensity (1000 tons CO ₂ /USD1million)	Carbon emission changes (1000tons CO ₂)	Carbon intensity (1000tons CO ₂ /USD1million)	Carbon emission changes (1000tons CO ₂)	Carbon emission changes (1000tons CO ₂)
Agriculture	0.07	548.60	0.06	−68.02	0.03	−112.35	368.23
Mining	0.37	−320.85	0.14	−10.48	0.13	−27.42	−358.75
Textile products	0.04	509.85	0.04	34.05	0.01	−12.29	531.61
Pulp, paper and wooden	0.11	−32.51	0.05	−24.02	0.05	−70.84	−127.37
Chemical	0.18	−1755.45	0.08	644.71	0.09	339.49	−771.25
Iron and metal	0.43	−2087.60	0.13	−388.63	0.11	−249.97	−2726.20
Motor vehicles and transport equipment	0.03	−278.10	0.01	−47.65	0.01	−0.56	−326.31
Electronic equipment	0.01	36.13	0.01	−20.37	0.02	−27.50	−11.74
Machinery and equipment	0.03	−323.51	0.01	39.41	0.01	−15.67	−299.77
Other manufactures	0.02	−16.75	0.01	−6.38	0.02	1.70	−21.43
Electricity, gas manufacture and water industry	12.26	−4101.43	4.80	644.45	1.78	552.37	−2904.61
Construction service	0.02	124.75	0.02	54.08	0.02	129.96	308.79
Other services	0.12	−105.25	0.08	−114.76	0.04	31.65	−188.36
Total	−	−7802.12	−	736.39	−	538.56	−6527.17

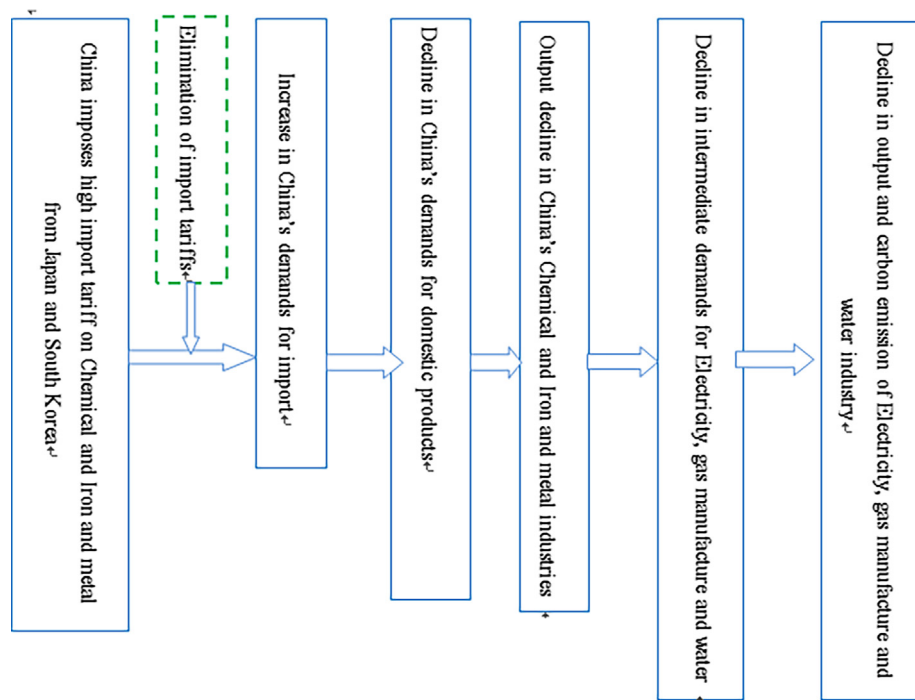


Fig. 4. Driving factors for carbon abatement in China's electricity, gas manufacture, and water industry.

metal industries as our analysis objectives and show the relationships in Fig. 4.

According to the GTAP 9.0 data, the import tariffs imposed by China on the chemical and iron and metal industries are 4.47% and 4.32% for South Korea and 5.50% and 4.70% for Japan, respectively. Therefore, when China eliminates the tariffs on imports from Japan and South Korea, China will experience significant increase of imported products in the two industries (Table 11). As for imported products having higher competitive advantages than domestic ones, demand for the latter will decline, and accordingly, output in the two industries will decrease (see Table 9). As a result, intermediate demand by the chemical and iron and metal industries for electricity, gas, and water will decline. Since this sector exists mainly to satisfy domestic demand

(limited exports), its output will decline accordingly, leading to considerable decrease in carbon emission. The above analysis indicates that the substitution of energy-intensive domestic products with non-energy-intensive imported products is the key reason underpinning China's carbon emission reduction.

6. Conclusion and policy implication

China, Japan, and South Korea are important economic entities in the world and are important trade partners to each other. The enormous economic demands, complementarity in economic structure, and geographically adjacency are all conditions favorable for a three-party FTA. However, friction and competition among the three countries,

disturbing factors outside the region, the unstable situation in the Korean Peninsula, and the opening up of Japan and South Korea's agricultural markets are all crucial factors hindering the development of a trilateral FTA. Despite their significant disparities, all three countries continuously strive to achieve regional economic integration with multiple rounds of negotiations. With big data analytics, this study quantitatively evaluates the impacts of the trilateral FTA by simultaneously using game theory and a general equilibrium model. It proposes a compromised scheme for the trilateral FTA, given Japan and South Korea's concerns regarding their agricultural product markets. The scheme was quantitatively evaluated from the viewpoint of the economy and carbon emission using a global trade analysis model. We also detail the impacts of the trilateral FTA on manufacturing and services industries.

The following conclusions were derived from the empirical analysis. First, the results of the game differ by interest index. The empirical results showed that from the economic growth perspective, all three countries would choose to cooperate with each other and set up the three-party FTA and from the employment perspective, they would maintain the status quo. Second, compared to the full opening of the agriculture market, the China–Japan–South Korea FTA with agricultural protection can not only stimulate economic growth in the countries but also reduce Japan and South Korea's agriculture-related concerns and unemployment pressure. Third, the trilateral FTA with agricultural protection can reduce carbon emission in Northeast Asia given the significant decline in China's carbon emission. With the exemption of the import tariff, China's consumers will substitute energy-intensive domestic products with non-energy-intensive imported products, which will reduce the output of most energy-intensive industries in China and further reduce carbon emission.

In addition to the effects of the trilateral FTA on each country's economy and employment, this study explored the influence of an FTA on carbon emission. The results indicated that China–Japan–South Korea FTA is conducive to control Northeast Asia's carbon emission, which is of considerable practical significance. In fact, because of the feeble recovery of the world economy and increasing global warming, determining a measure that achieves both economic growth and counters climate change is an urgent necessity. Northeast Asia is a pillar of growth in the world economy and economic integration will not only benefit locals but also contribute to global economic development. Importantly, China, Japan, and South Korea are all powerful nations with high carbon emissions. The control of carbon emission in these countries is crucial to counter climate change. Economic integration in Northeast Asia also has environmental benefits, indicating that economic growth and environmental improvement can co-exist. Such a finding is meaningful to the promotion of FTAs in other parts of the world. In fact, some scholars have researched the environmental effects of economic integration in the Asia-Pacific region in recent years. Lee et al. (2016), for example, analyzed the carbon emission of ocean transportation during economic integration in the Asia-Pacific region and found that global carbon emission under the condition of ASEAN Plus Three (Association of Southeast Asian Nations and FTA among China, Japan, and South Korea) would decline.

The study also found that the demand for imports from the chemical and iron and metal industries in Japan and South Korea will significantly increase with progress in trade liberalization. As there is a substitution effect between imported and domestic products, the domestic output of these energy-intensive industries will slightly decline; this is a noteworthy phenomenon. For long, the development of China's energy-intensive industries has not been properly guided owing to economic growth needs. The rapid development of energy-intensive industries has led to overcapacity (Wuttke, 2017), and the Chinese government has taken a series of corrective measures (Cui et al., 2015). The China–Japan–South Korea FTA will generate negative influences on China's chemical and iron and metal industries, which will undoubtedly aggravate the pressure on defusing overcapacity in energy-intensive

industries. Thus, China should take countermeasures in advance, enhance its technological R&D, increase the threshold for domestic market access, and accelerate the pace of industrial upgrade to avoid damage to its domestic economy from economic integration in Northeast Asia. The finding highlights the importance of lifecycle management of energy-intensive industries between China, Japan, and South Korea.

It is foreseeable that the trilateral FTA will undoubtedly undergo complex and fierce interest games and reaching a consistent solution in the short term seems unlikely. The establishment of the trilateral FTA involves a transnational and trans-departmental opening, which makes it necessary to focus on trade balance and economic interests. Constructing the China–Japan–South Korea FTA requires designing flexible strategies and a step-by-step principle. From the FTAs already signed by China, it can be said that flexible tariff reduction, that is, zero tariff, for most bilateral trade products, guarantees that the agreement members fully enjoy the benefits of trade liberalization. Simultaneously, considering the impacts on relevant parties from market opening, China can retain high tariffs on certain products, or make exceptional arrangements. Therefore, we suggest referencing the Early Harvest Program adopted by the China and ASEAN FTA during negotiations of the China–Japan–South Korea FTA. Countries can first adopt the Program, which includes products with rare vital interests, as a preliminary arrangement for the trade liberalization of agricultural products between China, Japan, and South Korea and gradually reduce the tariff level. In short, when promoting the FTA, the three countries should begin with overall and long-term interests in designing arrangements, share resources, and enhance cooperation to achieve the trilateral FTA smoothly.

However, this study has certain limitations. First, it only analyzes the China–Japan–South Korea FTA negotiations from the economic perspective without considering the influences of other factors such as politics. Second, this study set up the game matrix from the economic growth and employment perspective. Other economic factors may also affect negotiations among the three countries. Hence, future research should consider a more detailed game theory analysis of the China–Japan–South Korea FTA by constructing more decision-making indexes. Finally, this study adopts the global multi-region CGE model to quantitatively evaluate the economic effects of the trilateral FTA among China, Japan, and South Korea. This is a relatively static analysis, and we use 2011 as the benchmark for simulation, although the GTAP 9.0 database is the latest version. It is necessary to construct a dynamic GTAP model to explore the long-term effects of the trilateral FTA. Future studies should address all of these limitations.

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